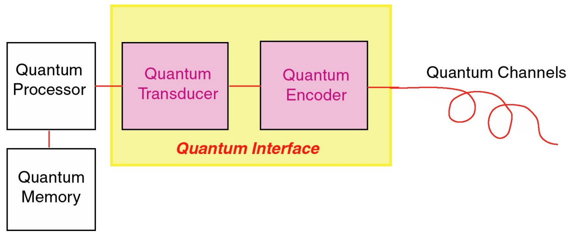
Quantum Information Physics: Theoretical Capabilities Solid State and AMO Implementation

Rochester-Stanford Center for Quantum Information

MURI, year started: 1999

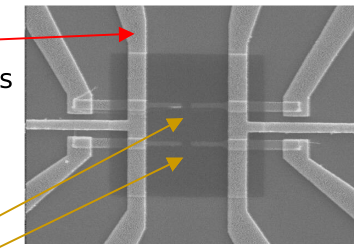
Objectives

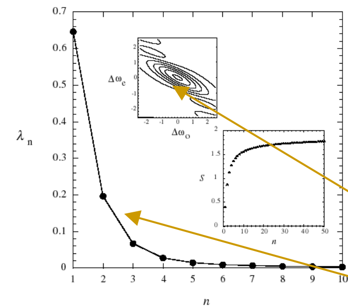
- Quantum Interfaces: Transferring entanglement between macroscopic systems



- Hardware toolbox for solid state implementation of quantum information processing chip, including spin-filter and decoherence-resistant electronic architectures.

GaAs/NiFe quantum point contact spin filters





Photon state-engineering for maximal Continuum-modal entanglement

Engineered bi-photon joint spectrum

Schmidt-mode eigenvalues

Approaches

- Quantum interference and entanglement in photonic, atomic, and electronic systems
- Quantum measurement and scaling in micro- and mesoscopic systems
- Experimental realizations of decoherence, gain, loss and entanglement transfer.
- Controllable coupling of Fermion-Boson entangled systems. (converting entangled electrons to photons.)

Present Status

Start date: 7/1/99

Collaboration with Rutgers, Lucent, Cornell and NEC

First joint workshop with Rochester group, 10/99.

“Fundamental Issues in Quantum Information”

Research Plan

Quantum Information:Theoretical Capabilities and Solid State Implementation

Center for Quantum Information, Stanford-Rutgers (C. M. Marcus, PI)

Year 1

- Develop required reading list. Understand present status of relevant fields, from classical information theory to solid state physics. Understand limitations of Holevo bound.
- Investigate the first generation of magnetic spin filters. Investigate spontaneous spin splitting in GaAs quantum point contacts

Year 2

- Generalize quantum information capacity bounds to include broadcast channels and multiuser systems.
- Begin simulations of coherent computer architectures.
- Test spin lifetimes using multiple point contacts in series.
- Realize Hanbury-Brown Twiss correlations for fermions in edge states.
- Fabricate superconducting tunnel junctions with bound states in the insulating layer.

Year 3

- Generalize Holevo's results for quantum channel capacity to include computational elements. Discover the crossover from information capacity to computational capacity.
- Realize robust, controllable spin filtering in the solid state.
- Demonstrate entangled quantum Hall edge states.
- Demonstrate pi-junctions using conventional superconducting tunnel junctions.

Years 4-5

- Formulate a general means of assessing the information theoretic advantage of quantum versus classical processing, for any given problem.
- Investigate scalability and decoherence in multiply interconnected quantum systems.
- Successfully test Bell inequalities in a solid state system. That is, show that quasiparticles, quantum Hall edge states, or superconducting Cooper pairs show correlations incompatible with any hidden variables theory.